ACTIVITY REPORT
ON
Sustaining Agriculture and Combating Land Degradation

1. Introduction

Production of food and fiber, and the maintenance and restoration of soil and water resources are vital to the Nation's welfare and global sustainability. Agricultural, forest, and range landscapes are important for commodity production, sources of water for municipal and industrial use, wildlife habitat, and a variety of other ecosystem services. The emphasis is not only on land directly used for production, but also for surrounding natural areas. Landscape health affects air quality, and water quality, and thus has potential consequences for human health. Combating land degradation includes monitoring public and private lands for indicators of decreased physical capacity of a landscape to produce food and fiber, function as a viable watershed, and maintain functional assemblages of plant and animal species for ecosystem health.

2. User Requirements.

Of the nearly 2.3 billion acres of land in the United States, approximately 650 million acres, or 28 percent, are owned by the Federal Government. Approximately 90 percent of all non-Federal lands, or about 1.5 billion acres, are in cropland, rangeland, pastureland, and private non-industrial forestland managed by millions of individuals. Thus users of earth observations range from strategic to production level decision makers in Federal, Tribal, and State governments, and industry, including land managers and individual producers. Agriculture and forestry are experiencing an information revolution largely focused on a demand for spatially-referenced earth observations. The demand for earth observations by producers is expected to increase dramatically if precision farming methods dominate as the preferred management practice. Decision makers in the United States require information on domestic and foreign agriculture, forestry, and landscape health, from the perspectives of maintaining U.S. competitiveness in the global economy, providing humanitarian aid, and maintaining global environmental quality.

Required earth observations encompass those for 1) *continually monitoring domestic and foreign production*, and 2) conducting *on-going audits of the status of baseline resources* required to sustain production, resource use, and landscape health. Earth observations are used for assessments of conditions at a point in time ("snapshot"), and for use in models to predict yield or resources status as a consequence of future outcomes of weather, management practices, biotic, and climate changes. There is a critical need to identify observations or *metrics* that can serve as *indicators* of environmental health status. Environmental indicators are scientific measurements or quantities derived from measurements that track environmental conditions over time. Indicators help measure the state of our air, water, biotic, and land resources, the pressures on them, and the resulting effects on ecological and human health. Indicators can be used to track progress towards making the air cleaner, the water purer, maintaining biodiversity, and protecting landscapes.

Major issues associated with sustainable agriculture, forestry, and efforts to mitigate landscape degradation include:

- Management and monitoring of domestic and foreign food and fiber production including risk management to maintain US economic competitiveness, and insure that world-wide production meets demands of increasing population.

- Monitoring landscapes for compliance with agreements between landowners/operators and federal and state agencies (e.g. Conservation Reserve Program (CRP), easements, timber sales, rangeland management).
- Monitoring for compliance with land management and use regulations.
- Monitoring for compliance with international treaties and agreements,
- Detecting, measuring, and monitoring contamination of soil, water and air resources.
- Metrics for maintenance of soil quality, especially organic matter, and chemistry.
- Detecting, measuring, and monitoring the impact of episodic catastrophic events such as drought, flood, hurricanes, tornadoes, volcanic eruptions, earthquakes and wildfires including impact assessment, and planning and monitoring of recovery and rehabilitation efforts.
- Detecting impacts and managing responses to global change, especially climate.
- Assessing and responding to soil erosion from wind and water.
- Detecting the presence, monitoring the spread, and assessing the effectiveness of efforts to eradicate invasive species, including plants, animals, and pests and diseases affecting agriculture, forestry, and natural resources.
- Assessing the status and changes of habitat and effects on plant and animal biological diversity.
- Mechanisms for early detection, and monitoring of the effects of and responses to bioterrorism (e.g. plant diseases, water-born pathogens).
- Measurements to identify, quantify, and manage factors influencing water quantity and water quality and air quality.
- Understanding, measuring and modeling greenhouse gas dynamics, especially factors relevant to carbon sequestration, and climate change.
- Measuring resources involved in the development and production of biofuels.
- Monitoring the transport, and fate of hazardous waste disposal.
- Measure the long-term effects of the use of ground water.

Data requirements for earth observations to support sustainable agricultural and forestry production and to combat land degradation are guided by user needs and a recognized set of principles. Measurements must be

- Timely: there is a need for frequent updates of observations; turn-around times from measurement and processing to delivery to users must be rapid.
- Consistent: measurements must be repeatable through time and space with precision,
- Calibrated: observations must be conducted in a manner that achieves a high degree of accuracy with a quantitative understanding of the errors associated with measurement and processing,
- Sustained: planned for long-term acquisition, or until a technological innovation arises that can provide a superior information solution,
- Comprehensive: providing a clear understanding of the status of, and changes in agriculture, forest, range, and natural area resources.
- Relevant: few decisions affecting natural resource management are made based on only one piece of information regardless of how precise the information is. Earth observation outputs must be placed in context.
- Standardized: allowing observations from diverse sources to be integrated. Compatible formats, units, calibrations are needed.

Attention must also be focused on:

- Spatial scale of observations: ranging from individual farm fields to the globe.
- Linking across scales without magnifying errors.
- Time-sensitive observations that must be rapidly acquired and reported.
- Validation of observations.

3. Deployed Systems and Earth Observation Commonalities

Users rely heavily on remotely sensed data from aircraft and satellite systems as a starting point for information. Wavelengths include visible, near infrared, short wave infrared, thermal infrared, microwave and RADAR. Optical wavelength multispectral systems dominate use because of their widespread availability. There is considerable research on applications of hyperspectral systems, despite the limited availability of these instruments. Technological advancements of imaging LIDAR and demonstrations of its utility are increasing.

Remotely sensed data from satelilites come from a variety of systems. The systems encompass high spatial resolution systems such as Ikonos, Quickbird and SPOT, the medium spatial resolution of Landsat Thematic Mapper (TM) and Terra ASTER, and spatially coarse resolution systems such as Terra-MODIS, SPOT-Vegetation, AVHRR, and GOES. Medium and coarse resolution satellite data is accessed whenever possible because of its global coverage capability, low cost, and attention to calibration by providers. High resolution satellite data is especially useful for areas where collection of data from aircraft is either infeasible or prohibitively expensive. The use of high-resolution satellite data has been limited by its relatively high cost and licensing restrictions.

Radar observations are accessed from RADARSAT, and from airborne systems deployed for specific objectives. Microwave systems are more limited in their use, primarily via satellite for SSM/I. Some airborne systems are used, however.

Airborne systems are of major importance to many users. There is considerable use of photographic systems ranging from small format aerial photography to large format aerial photography. Color and color infrared are preferred for most applications. Digital cameras and multispectral systems are increasing in use. There is limited use of hyperspectral imaging due to its decreased availability and need for specialized expertise during analysis. However, there is an increasing and robust body of research on the use of hyperspectral systems to measure leaf and canopy chemistry, crop yields, and plant health, not only for agriculture, but also as a general indicator of biosphere condition. Hyperspectral imaging capabilities will become an important tool for future agricultural and landscape ecosystem health monitoring. Airborne thermal systems are also being increasingly used in agriculture and forestry with a primary application being fire detection and mapping.

In-situ observations are conducted from both automated systems, and by individuals or organizations on an “as-needed” basis for specific program objectives. A number of existing *in situ* monitoring systems and programs could serve as a developmental model of future global ground based monitoring systems. Some of these include the projects and systems listed as Table 1.

Data distribution is becoming dominated by use of Internet Web site downloading tools. There is also considerable use of FTP, especially for large data sets. Use of postal services and shipping are still common especially for very large data sets, printed materials, and physical samples. This is especially prevalent for archived data not yet converted to digital form.

Table 1
Examples of U.S. Government Programs collecting detailed *in-situ* environmental data

Program	Type of Data	Agency	Website
AIRNow	Air Quality Data	USEPA	http://www.epa.gov/airnow/
BBS	Breeding Bird Survey	USGS	http://www.pwrc.usgs.gov/bbs/
CERCLIS	Hazardous Waste Sites	USEPA	http://www.epa.gov/superfund/sites/cursites/
EMAP	Environmental Monitoring & Assessment Program	USEPA	http://www.epa.gov/emap/
FIA	Forest Quality	USFS	http://www.fs.fed.us/pnw/fia/
GAP	Biological Resources	USGS	http://www.gap.uidaho.edu/
NRI	National Resources Inventory	USDA	http://www.nrcs.usda.gov/technical/NRI/
NWIS	Water Quality Data	USGS	http://waterdata.usgs.gov/nwis
STATSGO	Soil Parameters	NRCS	http://www.ncgc.nrcs.usda.gov/branch/ ssb/products/statsgo/index.html
PMP	Pesticide Monitoring Program	USDHHS	http://vm.cfsan.fda.gov/~dms/pesrpts.html
REVA	Regional Vulnerability Assessment Program	USEPA	http://www.epa.gov/reva/
USCRN	Climate Observations	NCDC	http://www.ncdc.noaa.gov/oa/climate/uscrn/
GAM	Geographic Analysis & Monitoring Program	USGS	http://gam.usgs.gov/
PINSAT	Pintail Duck Monitoring	USGS	http://www.werc.usgs.gov/pinsat/
BBS	Breeding Bird Survey	USGS	http://www.pwrc.usgs.gov/bbs/
NAAMP	North American Amphibian Monitoring Program	USGS	http://www.pwrc.usgs.gov/naamp/
GWA	Ground Water Atlas	USGS	http://capp.water.usgs.gov/gwa/gwa.html
BEST	Biomonitoring Environmental Status & Trends	USGS	http://www.best.usgs.gov/
AERONET	Aerosol Robotic Network	NASA	http://aeronet.gsfc.nasa.gov/

The following are the most significant common information needs:

- Land cover and land use within, and surrounding, a particular landscape or ecosystem: the required detail for meeting program objectives ranges from highly specific (crop type, species, plant community, etc.) to general (agricultural, forested, urban, etc.). Definitions of land cover vary by application, as do requirements for accuracy. Imagery ranging from panchromatic aerial photography to coarse resolution multispectral satellite data are used for land cover and land use analysis.
- Change detection of land cover, and plant, and animal species composition: it is important to assess short term changes such as within a growing season or long term ranging from years to decades or more.
- Weather data for domestic and international agricultural monitoring programs: There is considerable reliance on these data by organizations from sources such as NOAA, NASA, USAF, and WMO. Weather data is accessed in the form of weather station observations, radiosondes, multispectral satellite imagery, reports from weather observers, and other automated instruments such as AERONET for atmospheric optical properties. Some secondary data is obtained through measuring the quantity and timing of the streamflow in the Nation's rivers.
- Geolocation via the Global Positioning System (GPS): this has become a standard component of almost all earth observations. Real-time differential GPS methods access US National Differential GPS base station signals, FAA Wide Area Augmentation System (WAAS) signals, or commercially-available signals. Post-processed differential GPS corrections using Continuous Online Reference Station (CORS) data or other local base station data remains an important source of data for many applications. Kinematic GPS is used for in situ and airborne applications.
- Field data in the form of animal specimen locality records and vegetation plots are used for modeling habitat distribution, and calibrating remotely sensed spatial data, as well as for validation and accuracy assessment. Field data for operational purposes is frequently the most expensive to acquire.
- Topography in the form of a digital elevation map (DEM): This is commonly used as an element of base maps. Accuracy requirements range from sub-meter to tens of meters. Photogrammetric methods still dominate acquisition. RADAR, LIDAR and kinematic GPS are gaining in use.
- Geographic Information Systems (GIS): these have become a standard framework of operation for a significant number of users. GIS is employed as a tool during data collection, as a common platform for assimilating data from multiple sources, conducting analysis, and communicating information. Data and information are communicated via tables (i.e. statistics) and maps.
- Long-term data for change detection, calibration of algorithms, and species inventory: There is a need to continue converting historical imagery, maps, field notes, and data sheets to digital form.

The spatial scales for observations range from sub-landscape to global. The time scales range from hourly to decades. Applications demand more accurate and finer scale information as the intensity of land use increases and expands into less resilient soils, and less favorable climatic conditions.

4. Major Gaps and Challenges

Significant discontinuities of *in situ*, airborne and satellite data exist through space and time. Interpolation of *in situ* data using linear and weighted methods such as kriging, has become a standard element of data processing. A lack of timely data often forces a compromise of analysis and ultimately decisions based on the criteria. It is often difficult to engage the services of qualified airborne imagery providers when needed. Agency efforts to acquire complete "snapshot" coverage of the US for baseline resource audits require several years.

The significance of remote sensing imagery as a baseline data source for applications, coupled with concerns about data discontinuities through space and time communicates a strong message from users: there is a critical need for a dedicated land-observing system. Although users point to the benefits of Landsat imagery, the specific characteristics of an operational system of this *type* have yet to be determined. A design element of an operational Landsat-*type* system will be to eliminate as many spatial and temporal data discontinuities as possible. The development of an operational hyperspectral imaging capability, both at the aircraft and satellite levels, will be an important remote sensing and information resource.

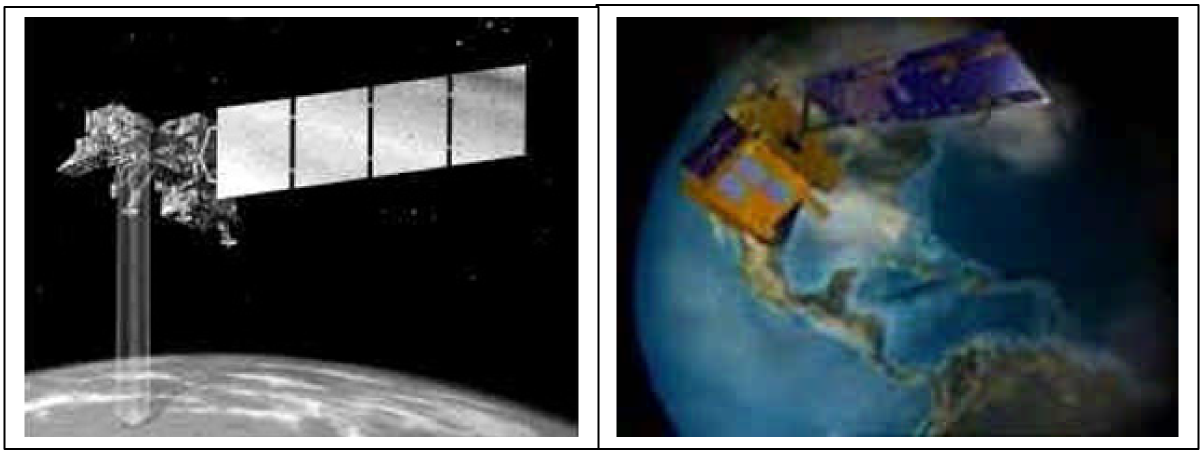

Figure 1. The continued availability of satellite imaging systems such as Landsat will be a critical operational data requirement. There is increasing interest in satellite systems with hyperspectral instruments such as Hyperion on the Earth Observer-1.

Remotely sensed soil moisture and precipitation are major data gaps. Maps of soil moisture are needed for management of production, drought forecast and monitoring, flood forecasting, and quantification of landscape health. Remotely sensed precipitation is needed to fill gaps of traditional weather station rain gauges and the limited coverage of *in situ* radar (NEXRAD). Other weather and climate-related observations such as incoming solar radiation are spatially sparse.

Environmental modeling is relatively spatially imprecise. While models can be very accurate at large scales or for an “average” situation, finer scale heterogeneity in resources and management practices restrict the utility for specific locations. As land management and agriculture applications continue to refine management systems and respond to niche markets, this heterogeneity is likely to be amplified. Similarly, information for profitable and sustainable operating systems will have to be very site specific to be of value. Thus, further model development, optimization, and validation are needed. This impacts earth observations as models 1) often only work for specific geographic regions, ecosystems, and species, and 2) often dictate what observations are to be taken. The complexities of ecosystem structure and function further enforce the need for interdisciplinary teams when building models. It is widely recognized that optimization and validation of models for specific locations and applications are critical. These complexities of landscape structure and function and management practices further enforce the need for interdisciplinary teams that can develop new technologies and methodologies to disaggregate process models to individual sites reliably and efficiently.

Challenges to conducting earth observations for sustainable agriculture and forestry, and combating land degradation are scientific, technological, economic, and organizational. Common data formats, units, instrument calibrations, and algorithms for data collection continue to be challenges for exchange and use of data.

Assessing ecosystem health requires applications that are precise enough to be used for site specific evaluations and span time scales long enough to detect trends in indicator variables.

The development of earth observation technologies has surpassed those currently employed for applications, such that users often lack the benefit of the latest advancements. The ability to *rapidly* infuse new observations into existing organizational infrastructure is a significant consideration. New or better observations may yield improved information for the application at hand, yet may be difficult to incorporate into an organization's operating procedures, or may not be comparable with previously collected observations.

The mission of regulatory agencies and those monitoring for compliance with program agreements and regulations demand accurate observations that are defendable when legal action is warranted. Careful attention to the selection of observations that will serve as metrics requires scientific and legal review by non-regulatory science agencies.

Expanding existing systems such as in situ networks or short-term measurement field campaigns is a continuing challenge. Such endeavors, although critical, rarely capture the attention of decision makers allocating yearly resources. Thus, important inventory and survey programs may be limited by funding cycles: monitoring ends with funding, award of graduate degrees. Collecting, synthesizing and interpreting resource health information is an important public service and critical to developing and implementing cost-effective conservation programs.

5. Partnerships

Partnerships exist between private land managers, Federal agencies, Conservation Districts, Resource Conservation and Development Councils, state and local conservation agencies and organizations, NGOs, state, local and tribal governments, rural communities, businesses, universities, and others. Cooperation among these organizations seek to increase agricultural productivity and efficiency, conserve natural resources, improve the environment, and enhance quality of life for rural areas. Federal, State and industry partners actively engage in education, research and conduct of earth observations. Individual companies exist that specialize in the conduct and analysis of specialized earth observations.

Types of partnerships include formal agreements that may include exchange of resources, or informal agreements to employ common standards, formats, strategies, etc. International partnerships foster education, research information management and aid via explicit political agreements or informally by scientific communities. Information management and exchange are emphasized by the participants. There is also exchange of earth observations by international industries. Satellite and airborne data such as SPOT, VMI satellite data are examples.

The most successful partnerships to address challenging agricultural and environmental issues cross disciplines, agencies, and national, and international boundaries. The Multi-Resolution Land Characteristics (MRLC) consortium, for example, was formed during 1992 between several Federal agencies to share the cost of acquiring satellite-based remotely sensed data. The MRLC consortium included the USGS, EPA, NOAA, USFS, NASA, and BLM. The MRLC leveraged common user requirements with the efficiency of combined federal agency purchase to acquire a national dataset of Landsat Imagery and to develop several LULC datasets. From the 1990s through the present, the MRLC resulted in several successful national mapping programs, including the: (1) Coastal Change Analysis Project (C-CAP) administered by NOAA; (2) Gap Analysis Project (GAP) directed by the Biological Resources Division of the USGS; and the National Land Cover Data (NLCD) project directed by both the USGS and EPA.

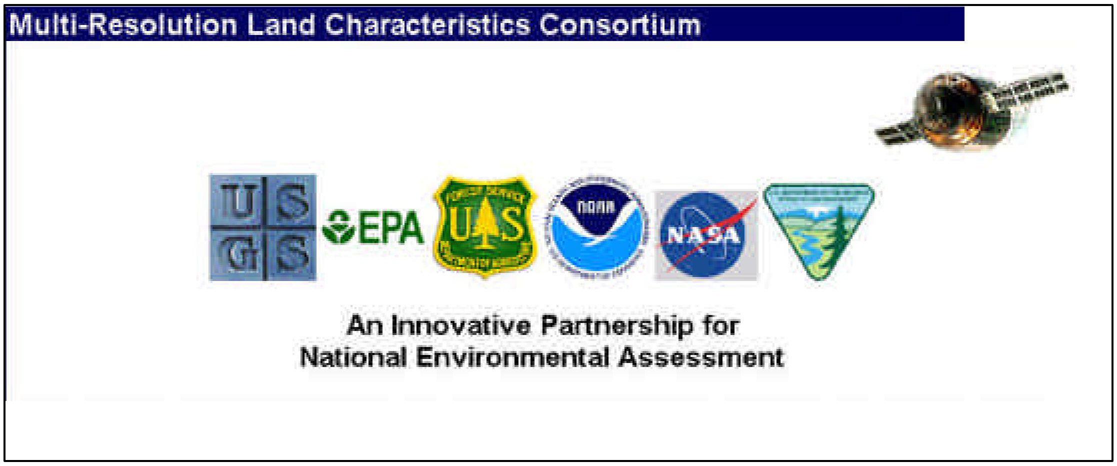

Figure 2. The Multi- Resolution Land Characteristics (MRLC) Consortium is an example of a Federal Agency partnership to acquire and develop remote sensing data and products.

6. U.S. Capacity Building

Capacity building is the development of human skills and capabilities, such as leadership, management, and technical expertise. The United Nations Development Program defined three critical elements to capacity building:

- the creation of an enabling environment with appropriate policy and legal frameworks;
- institutional development, including community participation
- human resources development and strengthening of managerial systems.

Currently, the most critical capacity building factors for the IWGEO will be; 1) the development of a formal, long-term governance mechanism, such as a charter or legal mandate, under which the program can continue, 2) the establishment of a human resources 'critical mass' of scientists and managers from all participating Agencies who are functionally 'dedicated' to the IWGEO mission, and, 3) the development of internal and external institutional linkages such as Interagency Agreements, Memorandums of Understanding between Federal Agencies and Grant and Assistance agreements for academia, non-governmental organizations and the research community.

Education builds scientific, agricultural, and environmental literacy. It recruits, retains, and graduates the best and the brightest of a diverse population, ensuring the value of future research. Multidisciplinary education to include new technologies, especially geospatial tools is an emerging trend. Education is also of benefit to earth observation users and earth observation providers. There is also a need to communicate the value of earth observations to decision makers, and the public. This includes expanding awareness of the utility of various earth observations, such as satellite data, to new applications.

Research and development is conducted by government, non-governmental organizations, and industry to address specific application requirements and translate science to specific applications at specific scales for specific locations.

Solving specific problems will require focused teams to address specific problems across disciplines, agencies, across national and international boundaries. Research that integrates biophysical, social, and economic skills is needed in areas such as detecting and responding to bioterrorism, regional water and air quality, biodiversity management, and the incursion of invasive species.

Research and development to meet information needs by translating science to technology require partnership teams to pose and solve problems across disciplines, agencies, national, and international boundaries. International aid and cooperative research programs are focused on providing assistance for earth observation programs and training scientists within developing countries.

7. Future Earth Observation Systems

Several future systems will provide data of interest to sustainable agriculture and efforts to combat land degradation:
- Landsat-follow-on – its form TBD.
- Hydros for soil moisture.
- NPOESS as a source of high quality coarse scale resolution imagery.
- The next generation of geostationary satellites: the use of imagery from these systems is underutilized. Recent exploitation of these systems suggests that its use is expected to increase.
- Digital airborne systems are expected to replace most, if not all, photographic airborne systems.
- *In situ* automated systems are gaining in reliability and are being expanded. Networks include such as SCAN, AERONET, NSIP, FLUXNET, automated weather stations, etc. Locations of such systems on LTER and experimental watersheds are expected to expand as these research facilities expand and become long-term.
- Others TBD.

8. Summary

The Agriculture team is currently discussing the following topics for the conduct, sharing and use of earth observations needed to support sustainable agriculture and combat land degradation:

- The greatest unfulfilled requirement is the need for an operational Landsat-*type* satellite remote sensing system that can deliver time-sensitive information.
- Linking observations across scales while constraining errors requires specific attention to scaling methodologies.
- Integrating earth observations into decision models employed by decision makers at local and strategic levels and guiding how, when and where to conduct earth observations by inputs needed for the models.
- Maximizing the awareness of and access to data via new organizational and technological insights.
- Conducting research to optimize models and systems for specific applications and geographic locations.
- Fostering partnerships and collaborations across disciplinary, organizational, national and international boundaries to address earth observations needs. Researching scientific, technological and organizational requirements to accomplish this.
- Developing organizational mechanisms, and technologies to ensure long-term observations are made and centrally archived.
- Standardizing and coordinating *in situ* data collection.

A dedicated global land observation system, based on *in-situ*, airborne, and satellite systems, both research and operational is suggested. An agricultural monitoring system would function as part of the system. A critical element will be developing the technology to make earth observation data available to users rapidly. Making such a system successful will require users at both strategic and production levels to re-examine what types of earth observations are used, how the data are used, how the data are accessed, and how the data are incorporated into an organizational infrastructure for analysis.